February 7, 1867.

Lieut.-General SABINE, President, in the Chair.

The following communication was read:—

"Account of Experiments on Torsion and Flexure for the Determination of Rigidities." By J. D. EVERETT, D.C.L., Assistant to the Professor of Mathematics in the University of Glasgow. Communicated by Sir WILLIAM THOMSON. Received January 25, 1867.

(Abstract.)

These experiments are a continuation of those described in a paper read February 22, 1866, with some modifications in the apparatus employed which render the comparison between torsion and flexure more direct. The amount of torsion or flexure produced by subjecting a cylindrical rod to a uniform couple throughout its whole length, is measured by means of two mirrors clamped to the rod near its ends, in which, by the aid of two telescopes, the reflexions of a scale overhead are seen and the displacements read off. One end of the rod is fixed, and a couple (of torsion and flexure alternately) is applied to the other end.

Three rods, of glass, brass, and steel, were experimented on, and the results obtained were as follows—M, n, and k denoting the resistances (in kilogrammes per square millimetre) to linear extension, shearing, and cubical compression respectively, and σ denoting the ratio of lateral contraction to longitudinal extension:—

	Glass.	Brass.	Steel.
Value of M......	5851	10948	21793
„ n	2390	3729	8341
„ k	3533	57007	18756
„ σ	·229	·469	·310

February 14, 1867.

Lieut.-General SABINE, President, in the Chair.

The following communications were read:—

I. "On the Relation of Insolation to Atmospheric Humidity." By J. PARK HARRISON, M.A. Communicated by the President. Received January 30, 1867.

The occurrence of the maxima of insolation on days of great relative humidity which was noticed by Herr v. Schlagintweit in India*, receives

* Proceedings of the Royal Society, 1865, vol. xiv. p. 111.

confirmation from the fact that the post-solstitial periods of maximum solar radiation in autumn, and also the diurnal maxima, coincide with monthly and daily periods of maximum humidity.

It is proposed to show the extent to which this is the case in England by means of Tables of monthly results of radiation and vapour.

The first Table exhibits the mean monthly values of solar radiation and vapour-tension for the five months from May to September, at Greenwich, in 1860-64*.

TABLE I.

Monthly Means of Radiation and Vapour at Greenwich (1860–64).

Month.	Solar radiation.	Tension of vapour.	Weight of vapour.
May	$97^{\circ}\cdot8$ F.	0·314 in.	3·5 grs.
June.........	103·2	0·364	4·1
July	+108·2	+0·393	+4·4
August......	+107·5	+0·397	+4·4
September..	97·5	0·361	4·0

The plus signs (+) indicate first and second maxima.

The maxima, both of radiation and vapour, occur in July and August. The excess of insolation in July is 5°, and the excess in August $4^{\circ}\cdot3$ above the mean in June. The excess of vapour-tension in the two months is ·030.

To obtain results more exactly comparable, the monthly mean tension of vapour for each of the five months was next deduced at the hours of noon, 2 P.M., and 4 P.M., for the years 1842–47, during which two-hourly observations were made at the Royal Observatory.

In Table II., which contains the monthly means, maximum results again appear principally in July and August.

TABLE II.

Monthly Means of Tension of Vapour at Greenwich at 0^{h}, 2^{h}, and 4^{h}.

Year.	May.	June†.	July.	August.	September.
1842.	0·358	0·473	0·436	0·545	0·449
1843.	0·390(*a*)	0·414	0·501(*b*)	0·509	0·474(*c*)
1844.	0·365	0·429	0·466	0·430	0·450
1845.	0·331	0·493	0·463	0·443	0·402
1846.	0·379	0·483	0·484	0·496	0·471
1847.	0·376	0·391	0·484	0·497	0·403

(*a*) Mean amount of cloud 8·0. (*b*) Cloud 8·5. (*c*) Cloud 4·5.

* The vacuum-thermometer was used at Greenwich first in 1860. 1864 is the date of the last published observations. The means of radiation were derived from the daily maxima of the vacuum-thermometer; the means of vapour from the usual number of diurnal observations. It is believed that the observations for the five years are homogeneous.

† See note *, p. 358.

And the monthly maxima of solar radiation (in the next Table) accord with the higher mean tensions of vapour in almost every instance.

TABLE III.

Monthly Mean Maxima of Solar Radiation.

Year.	May.	June*.	July.	August.	September.
	°	°	°	°	°
1842.	82·1	98·9	92·4	102·2	81·7
1843.	80·9(*a*)	85·1	90·9(*b*)	93·0	92·6(*c*)
1844.	87·5	95·0	94·1	87·2	87·0
1845.	75·0	93·1	90·3	(91·7)†	81·3
1846.	87·1	103·1	97·4	93·3	90·3
1847.	86·3	85·7	93·0	89·0	77·6

(*a*) Mean amount of cloud 8·0. (*b*) Cloud 8·5. (*c*) Cloud 4·5.

In those cases where the values of radiation and vapour do not agree, the exceptions will, it is believed, be sufficiently accounted for; thus the occurrence of the second maximum of solar radiation in September 1843 in place of July, though tension was higher in the latter month, is explained by the obscuration of the sun, and the unusual quantity of rain in July. The tension of vapour in September was ·06 higher than in June‡.

Heat and Vapour in Canada.—The dependence of the maximum temperature in the day on the quantity of moisture in the air, in winter, at Toronto, though not directly connected with the present inquiry, is closely allied to it, and may be referred to with advantage in the absence of observations of solar radiation, to show the effects of slight variations of vapour in that country.

General (at that time Colonel) Sabine, in a paper in the Transactions of the Royal Society "On the Periodic and Non-Periodic Variations of Temperature at Toronto"§, pointed out the fact that the period of minimum heat in the year, both hourly and daily, at that station occurs between the 7th and 17th days of February, on the days when vapour is also at its minimum. The means of temperature and tension on the ten days

* In June the maxima of radiation are, as a rule, found to be accompanied by less vapour than in August and September. Thus it will be seen in Tables II. and III. that the difference between the mean tensions in June and August 1846 is ·013; the excess is in favour of August; but the maximum solar radiation is in June. In 1843 tension was at its maximum in July—but not radiation, in consequence of the abnormal quantity of cloud and rain in that month.

† Six observations only.

‡ A still more remarkable instance of monthly maximum solar radiation in September occurred in 1865, when the excess over the mean of the five preceding Septembers was 21°·7, and the increase of contemporaneous vapour-tension ·086. This appears to be accounted for by the rainfall in August; the weather in September 1865 was, in fact, very like that which follows the rainy season in India. The tension of vapour was ·084 higher than in June.

§ Anno 1853, p. 148.

alluded to are respectively 21°·7 and ·098, as deduced from the hourly observations which were taken in 1842–48 at the Ordnance Office.

The mean readings of the standard thermometer at 2 P.M. (the warmest hour in the winter at Toronto) and the contemporaneous mean tensions of vapour, in January and February, are exhibited in Table IV.

TABLE IV.

Monthly Mean Results at Toronto at 2^h P.M. (1842–48)*.

Month.	Maximum temperature	Wet-bulb thermometer.	Tension of vapour.
	°	°	
January ...	28·6	26·7	0·129
February...	28·3	25·9	0·117

At 2^h on the 7th to the 17th days of February the temperature was 26°·4, and the mean tension of vapour ·111.

Postmeridian maxima of solar radiation.—Though, it is well known at observatories, the hour of mean maximum solar heat occurs in this country after midday, there is no numerical proof of the fact available, excepting the results of six days' observations by Professor Daniell. From experiments made by him in June (1822) at every hour between 9^h 30^m A.M. and 7^h 30^m P.M., the mean highest readings of a black-bulb thermometer were obtained between 1^h 30^m and 2^h. The following are the means for five days:—

	h	m		°
At	10	30	....	46
	12	30	....	63
	1	30	....	65
	2	30	....	63†

It may be assumed, then, that on days when the sun is shining both in the morning and afternoon, solar radiation is of highest apparent force after 0^h‡.

Daily maxima of vapour.—The means of vapour-tension have been deduced at 10^h A.M., noon, and 2^h from the bi-horary observations at Greenwich in 1842–47; the following Table, which contains the monthly results for each of these hours, shows that the means at 2^h are higher than those at 10^h A.M., or at noon, in every month from March to September:—

* From Tables LV., LVIII., and LX., Toronto Observations, vol. ii. The maxima of heat and vapour occur at Toronto in July and August, vapour-tension at 2^h in July being ·069 higher, and in August ·108 higher than in June.

† Daniell's 'Meteorology,' vol. ii. p. 113.

‡ Ibid. pp. 114–118. On another favourable day in June, Professor Daniell obtained the following results with a solar thermometer covered with black wool:—at 10^h A.M. 111°; at noon 129°; at 2^h P.M. 143°; at 2^h 30^m P.M. 138°. Since this paper was in type, I find these results are confirmed by observations made in March 1858 by Mr. H. S. Eaton.

TABLE V.

Monthly Means of Vapour-Tension at Greenwich at 22^h, 0^h, and 2^h (1842–47).

Hour.	March.	April.	May.	June.	July.	August*.	Sept.
h							
22	·236	0·284	0·357	0·437	0·462	0·473	0·427
0	·246	0·294	0·365	0·446	0·469	0·483	0·441
2	+·249	+0·297	+0·368	+0·449	+0·475	+0·486	+0·444

The mean increase of vapour from 10^h to noon is ·010; and the mean increase from noon to 2^h is ·0034. In six of the months the mean increase is in each case ·003†.

The results accord with the assumed date of maximum radiation.

Actinometer-observations.—The observations of the actinometer made by Mr. Nash at the Royal Observatory in 1864 supply further evidence of the fact that the maxima of radiation occur in the autumn, and after 0^h.

I have extracted the mean results of the several groups of observations which were taken at or near the same elevation of the sun, in the months of August and September in autumn, and in the months of March and April in spring, and find that the value of the mean increase of the scale-readings in the autumn is about 100 per cent. greater than in the spring‡.

The mean increase of the scale-readings in March and April is 19·4.

The mean increase of the scale-readings in August and September is 39·6.

The difference is 20·2, at the same mean altitude of the sun.

The means of the contemporaneous observations of the vacuum-thermometer on the grass were as follows:—

In March and April .... 70°·3 F.
In August and September ... 84°·7 F.

The difference is 14°·4.

And the mean tension of vapour for the four months is, in March and April ·23, and in August and September ·34.

* August is the only month in which the mean tension of vapour is higher at 4^h P.M. than at 2^h P.M.

† With the exception of July (when there is the minimum difference of ·007 between the results at 10^h A.M. and noon) and of September (when there is the maximum difference ·014), the mean increase in tension at noon in the several months is also remarkably regular.

‡ See 'Greenwich Meteorological Results,' 1864, p. xxxviii.

TABLE VI.

Mean Results of Actinometer-observations at Greenwich, March and April 1864.

Month and day.	Mean solar time.	Mean results in scale-divisions.	Altitude of sun.	State of sky.
	h m		°	
March 23.	2 29	18·7	30	Light cirri.
15.	22 23	14·2	32	Cloudless.
18.	2 9	21·1	32	Clear.
18.	0 36	20·4	36	Clear.
24.	1 32	17·0	36	Clear.
15.	23 51	19·1	37	Clear. Light cloud.
April 15.	2 26	27·1	37	Clear.
20.	2 28	25·5	38	Light cirri prevalent.
March 24.	0 49	14·3	39	Clear.
Means.	......	19·4	35	Clear.

TABLE VII.

Mean Results of Actinometer-observations at Greenwich, August and September 1864.

Month and day.	Mean solar time	Mean results in scale-divisions.	Altitude of sun.	State of sky.
	h m		°	
August 30.	3 26	41·6	30	Cloudless (thunder in evening).
September 14.	22 8	43·3	34	Sun free from cloud.
14.	22 12	34·7	35	Light cirri over sun.
August 26.	3 0	38·3	35	Sun free from cloud.
26.	2 55	32·4	36	Sun free from cloud.
29.	2 39	40·1	36	Clear (amount of cloud in afternoon 9, cirrocumuli, cirrus).
5.	3 3	41·7	39	Cloudless.
Means	......	39·6	35	Cloud genera lre-sent.

Of the very few observations in May and July which were available for comparison, the scale-readings in July were found to reach far higher values than in May *.

* The observations at altitudes between 24° and 29° in March and October showed similar results. Below 24° and above 60° there were no observations that were comparable.

TABLE VIII.

Results of Actinometer-observations in May and July 1864.

Month and day.	Mean solar time.	Mean results in scale-divisions.	Altitude of sun.	State of sky.
	h m		°	
May 16.	2 17	28·3	47	Cloudless*.
16.	0 28	21·4	56	Cloudless.
16.	0 14	23·7	57	Cloudless.
July 11.	2 19	46·7	50	Clear about sun.
5.	1 7	36·6	58	Clear.
13.	23 18	39·3	58	Cloudless.

The mean tension of vapour in May was ·30, in July ·38.

The last Table contains, in parts of scale, the results of groups of observations near midday and 2 P.M., on three days, in March, May, and July. The maximum in each case occurs at the later hour.

TABLE IX.

Actinometer-observations at 0^h and 2^h.

Month and day.	Mean solar time.	Mean result in scale-divisions.	Altitude of sun.	State of sky.
	h m		°	
March 24.	0 49	14·3	39	Clear throughout.
24.	1 32	17·0	36	Clear.
May 16.	0 28	21·4	56	Cloudless.
16.	2 17	28·3	47	Cloudless.
July 14.	23 37	48·6	59	Cloudless.
14.	2 13	57·6	50	Cloudless.

The great accordance between the foregoing results renders it unnecessary to adduce further evidence of the occurrence of maximum insolation some considerable time after the summer solstice and after 5^h.

Increased solar radiation supposed to be due to the action of aqueous vapour.—Herr von Schlagintweit, applying Professor Tyndall's discovery of the absorptive properties of aqueous vapour to the phenomenon of insolation, attributed the high readings of his solar thermometer, in certain parts of India, to the fact that air, when highly charged with moisture, impedes free radiation; that is to say, the air restores to the instrument some portion of the heat which has been radiated off from it.

A like cause has been recently assigned for the variations in temperature which take place on clear nights in Madras under different tensions of va-

* Compare observations on the same day at 0^h 28^m and 0^h 14^m.

pour, those nights being considered clear in which the percentage of cloud did not exceed ·10. It was found, on a careful tabulation of hourly observations, that the fall in temperature was decidedly greater when the quantity of vapour was relatively small*.

Cloud, haze, and opalescence† *of the atmosphere more probably the principal cause of the phenomenon.*—It appeared of much importance to ascertain whether the presence of cloud, and the imperfect state of transparency in the sky which usually accompanies it, may not have materially assisted in producing the results alluded to in the last paragraph, and, *à fortiori*, account for the increased insolation noticed in cloudy weather in various parts of India—*e. g.* "on days in the rainy season when the clouds are temporarily broken," and, as in Sikkim, "when a break in the clouds of an hour or two had to be watched for to obtain observations of solar radiation" (Schlagintweit, 'Meteorology of India,' pp. 49 & 51).

To test this point, the results of the observations for the four years ending 1844, over which the inquiry at Madras extended, were divided into groups of contemporaneous observations of temperature, vapour-tension, and percentage of clear sky, when the mean numerical results showed that a progressive fall of about 1° F. for every ·10 of vapour-tension was accompanied by a proportionate increase in the percentage of clear sky,—a result which is the more significant when it is considered that the infusion of visible cloud was limited to ·10.

To prevent mistake, the fall in temperature on the nights of maximum clearness was compared with the fall on nights of minimum clearness within the limits above stated. There were twenty-five nights which were estimated to be perfectly clear, and twenty-two nights when the per. centage of clear sky ranged from ·90 to ·93, the average being ·915 (1·000 representing an entirely clear sky). The results were as follows:—

The mean fall of temperature at an estimated clearness of sky denoted by 1·000 was 8°·3 F.

The mean fall of temperature at an estimated clearness denoted by ·915 was 6° F.

The difference is 2°·3. The contemporaneous mean tensions of vapour were ·68 and ·83 respectively.

It is probable then, as cloud accompanies humidity, that tension of vapour gives some indication of the *state of transparency of the sky*, whilst affording a measure of the quantity of invisible vapour in the air.

In any case it is sufficiently clear, both from the results at Madras and from the slight increase in the tension at 2^{h} P.M., that the amount of aqueous vapour alone is not sufficient to account for increased or diminished solar radiation.

* Phil. Mag. October 1866; where see Tables and method of deduction.

† This term was first used by Professor Roscoe. It here represents the state of the atmosphere at the moment vapour is in process of condensation previously to its formation into cloud.

The explanation of the phenomenon of the maxima of insolation occurring on days of great relative humidity in India, however, which has been already alluded to, applies with increased force to the absorptive properties of visible moisture ; and the known action of even the lightest form of cloud in radiating heat to the earth, would point to this as the principal cause of the phenomenon, though it cannot be doubted that some of the effect is due to the action of invisible vapour, whether as warmed directly by the solar rays, or by heat derived from a secondary source.

The dependence of terrestrial heat on vapour and cloud.—It was to increased or diminished radiation under a clear or clouded sky that the inflections of the curves of mean temperature, which I communicated to the Royal Society in May 1865, were ascribed*. The effects produced were on that occasion considered to be principally due to radiation at night†; but an examination of the daily means proved that a similar action occurred also by day‡,—the phenomenon in fact depending, as in the case of solar radiation, on the quantity of moisture in the air.

The precise values of heat resulting from the action and reaction of solar radiation and vapour cannot be ascertained until mean numerical values have been deduced from a sufficient number of hourly observations to afford trustworthy data for determination. The present paper merely helps to establish a relation between solar radiation and humidity, and suggests an additional cause for the effects which appear to follow from it.

* It has since been found that the value of the difference of temperature for fifty years at Greenwich, due to terrestrial radiation, was very much understated by me, principally from the fact that the mean temperatures for the greater part of the entire period had been corrected by quantities in the Philosophical Transactions which were afterwards found to be erroneous, and have been disused at Greenwich for several years. All the conclusions which were based specially on the results for fifty years must therefore be considered as withdrawn.

The results derived from the more perfect means for periods of seven and eight years are confirmed by the Oxford thermographs, and by almost identical results which I find were obtained by Dr. Mädler from fifteen years' observations at Berlin nearly thirty years ago.

† See also 'Lectures on Scientific Subjects,' by Sir John Herschel, 1866, p. 149 (10

‡ British Association Reports, 1859, p. 198.

Appendix.

No. 1.

Monthly Mean Maximum Solar Radiation at Greenwich (1860–64).

Year.	May.	June.	July.	August.	September.
1860.	103°·7	101°·0	105°·6	103°·5	97°
1861.	96·7	108·6	114·5	116·5	106·9
1862.	99·6	103·1	109·4	110·7	99·8
1863.	95·7	104·1	107·2	106·5	92·9
1864.	93·1	99·3	103·7	100·1	90·7
Means *	97·8	103·2	108·2	107·5	97·5

No. 2.

Monthly Mean Tension of Vapour at Greenwich (1860–64).

Year.	May.	June.	July.	August.	September.
1860.	0·312	0·357	0·393	0·396	0·364
1861.	0·284	0·404	0·413	0·436	0·369
1862.	0·365	0·352	0·394	0·410	0·396
1863.	0·302	0·364	0·384	0·412	0·320
1864.	0·306	0·344	0·382	0·333	0·357
Means *	0·314	0·364	0·393	0·397	0·361

No. 3.

Monthly Mean Weight of Cubic Foot of Air at Greenwich (1860–64).

Year.	May.	June.	July.	August.	September.
	grs.	grs.	grs.	grs.	grs.
1860.	3·5	4·0	4·4	4·4	4·1
1861.	3·2	4·6	4·6	4·9	4·1
1862.	4·0	4·0	4·5	4·6	4·4
1863.	3·4	4·1	4·3	4·5	3·6
1864.	3·5	3·9	4·2	3·7	4·0
Means *	3·5	4·1	4·4	4·4	4·0

* Extracted from Greenwich Observations.

No. 4.

Vapour-Tension at 10^h A.M. at Greenwich (1842–47).

Year.	March.	April.	May.	June.	July.	August.	Sept.	Oct.
1842.	0·263	0·255	0·354	0·453	0·425	0·527	0·442	0·285
1843.	0·260	0·302	0·383	0·400	0·467	0·498	0·461	0·304
1844.	0·238	0·320	0·352	0·412	0·452	0·423	0·435	0·330
1845.	0·187	0·282	0·323	0·467	0·459	0·432	0·382	0·349
1846.	0·261	0·298	0·361	0·516	0·491	0·494	0·465	0·354
1847.	0·210	0·248	0·372	0·377	0·481	0·465	0·376	0·375
Sums	1·419	1·705	2·145	2·625	2·775	2·839	2·561	1·997
Means *	0·236	0·284	0·357	0·437	0·462	0·473	0·427	0·333

No. 5.

Vapour-Tension at *noon* at Greenwich (1842–47).

Year.	March.	April.	May.	June.	July.	August.	Sept.	Oct.
1842.	0·280	0·270	0·358	0·470	0·437	0·546	0·447	0·315
1843.	0·271	0·309	0·390	0·407	0·493	0·499	0·478	0·324
1844.	0·250	0·337	0·358	0·423	0·459	0·429	0·456	0·343
1845.	0·190	0·295	0·331	0·488	0·462	0·445	0·397	0·354
1846.	0·266	0·305	0·377	0·498	0·489	0·491	0·470	0·356
1847.	0·219	0·247	0·375	0·388	0·476	0·491	0·396	0·389
Sums	1·476	1·763	2·189	2·674	2·816	2·901	2·644	2·081
Means *	0·246	0·294	0·365	0·446	0·469	0·483	0·441	0·347

No. 6.

Vapour-Tension at 2^h P.M. at Greenwich (1842–47).

Year.	March.	April.	May.	June.	July.	August.	Sept.	Oct.
1842.	0·284	0·269	0·355	0·472	0·435	0·546	0·447	0·317
1843.	0·273	0·318	0·393	0·419	0·501	0·508	0·476	0·324
1844.	0·253	0·346	0·370	0·432	0·470	0·431	0·453	0·346
1845.	0·197	0·292	0·333	0·496	0·469	0·445	0·408	0·346
1846.	0·271	0·311	0·379	0·485	0·488	0·491	0·473	0·357
1847.	0·218	0·245	0·381	0·392	0·486	0·496	0·407	0·381
Sums	1·496	1·781	2·211	2·696	2·849	2·917	2·664	2·071
Means *	0·249	0·297	0·368	0·449	0·475	0·486	0·444	0·345

* The means are inserted in Table V.

Fall of temperature at Madras, by nights :—

1.

Entirely clear sky (1·000).

25 nights.

°
4·5
7·1
8·5
7·7
7·6
11·2
9·5
9·5
9·1
6·9
9·6
9·6
12·2
8·1
9·4
6·6
8·2
4·9
6·5
8·7
8·2
7·5
10·6
9·4
6·5
25) 207·6
8·3

2.

Partially clouded sky (·915).

22 nights.

°	Percentage of clear sky.
4·8	·900
6·2	
5·9	
8·4	
4·6	·910
5·0	
7·5	
7·6	
5·3	
5·4	
5·8	
8·5	
3·6	·920
7·2	
7·6	
5·0	
6·7	
5·7	·930
4·2	
6·4	
4·9	
6·3	
22) 132·6	
6·0	·915 Mean.

At Fort Franklin, Sir John Richardson found that the maximum of solar radiation was obtained in the *spring* and at noon. Mr. Forbes accounted for this by the fact that the sun's rays were reflected from the *snow,* and thus the bulb of the thermometers received reflected as well as direct rays of sunshine.

II. "On the Conversion of Dynamical into Electrical Force without the aid of Permanent Magnetism." By C. W. Siemens, F.R.S. Received February 4, 1867.

Since the great discovery of magnetic electricity by Faraday in 1830, electricians have had recourse to mechanical force for the production of their most powerful effects; but the power of the magneto-electrical machine seems to depend in an equal measure upon the *force expended* on the one hand, and upon *permanent magnetism* on the other.

An experiment, however, has been lately suggested to me by my brother, Dr. Werner Siemens of Berlin, which proves that permanent magnetism is